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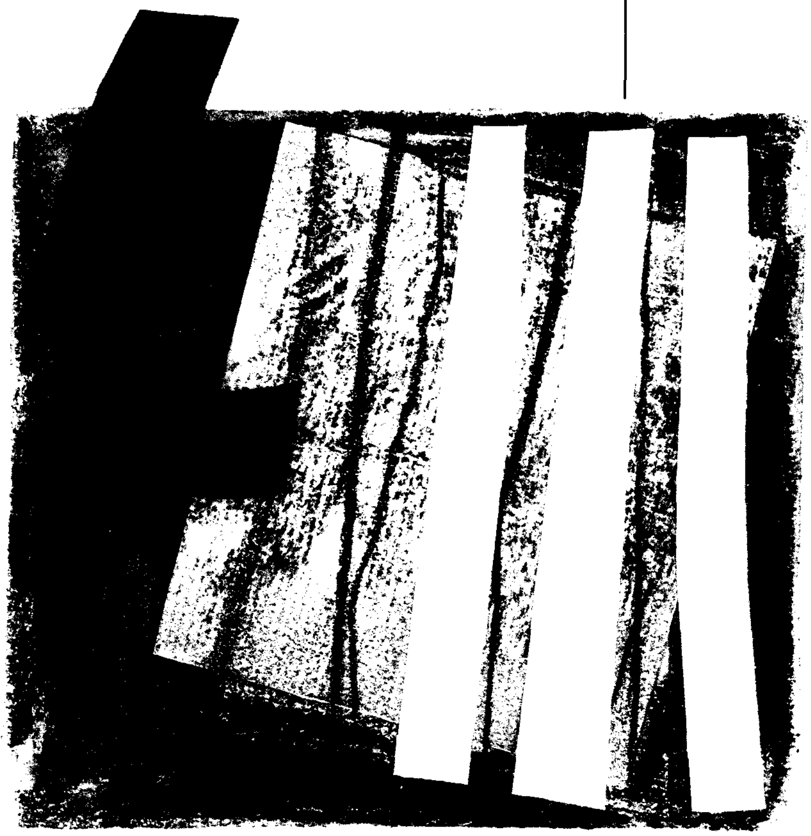

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Departamento de Economía de la Empresa
Universidad Carlos III de Madrid
Calle Madrid, 126
28903 Getafe (Spain)
Fax (341) 6249608

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Miguel A. Martínez[1], Mikel Tapia[2] and Gonzalo Rubio[3]

Abstract

This paper estimates a new measure of liquidity costs in a market driven by orders. It represents the cost of simultaneously buying and selling a given amount of shares, and it is given by a single measure of liquidity which is just an increasing function relating bid-ask spreads with size. This measure completely characterizes the cost of liquidity of any given asset. It does not suffer from the usual ambiguities related to either the bid–ask spread or depth when they are considered separately. With a single measure, we are able to capture all dimensions associated with liquidity costs. The seasonality behavior of the liquidity cost is also analyzed.

Keywords: liquidity function, liquidity cost, open limit order book, bid-ask spread, depth, adverse selection.

JEL classification: G14

[1] Universidad del País Vasco. Dept. Fundamentos, Facultad de Ciencias Económicas. Avda. del L. Aguirre, 83, 48105 Bilbao, Spain. E-mail: jepmasem@bs.ehu.es
[2] Universidad Carlos III de Madrid. Dpt. Economía de la Empresa. C/ Madrid, 126, 28903, Getafe, Madrid, Spain. E-mail: mtapia@emp.uc3m.es
[3] Universidad del País Vasco. Dept. Fundamentos, Facultad de Ciencias Económicas. Avda. del L. Aguirre, 83, 48105 Bilbao, Spain. E-mail: jepruirg@bs.ehu.es

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Understanding liquidity:
A closer look at the limit order book

1. Introduction

It is clearly recognized that liquidity benefits the individual investors in securities markets. Generally speaking we all understand that liquidity somehow reflects the ability to trade basically costlessly. Hence liquid markets should be able to accommodate large amounts of trading without distortioning impacts on prices.

Unfortunately, however, what this really means in practice, or even in a formal analytical sense is much less clear. We might use the idea of Kyle (1985) in which liquidity measures the order flow needed to change prices one unit. Note that this concept lies on the use of the aggregated order flow, so that it might be argued that from the point of view of individual investors, the relative bid-ask spread is a more appropriate measure of liquidity. Of course, the market will be more liquid the lower the bid-ask spread.

Nevertheless, Easley and O'Hara (1987) and O'Hara (1995) argue that there may not be a single spread as long as prices vary with trade size. In fact, they show that the bid-ask spread for large trades may be considerably larger than the spread for small trades. This is a consequence of the spread arising as a compensation for the risk of trading with individuals who have superior information. The spread needs not to be constant across quantities.

This is the basis of the reasoning provided by Lee, Mucklow and Ready (1993) who argue convincingly in favor of the bidimensionality aspect of liquidity. The cost faced by an indivual who wishes to trade simultaneously buying and selling shares, which of course reflects the cost of immediacy, must have a quantity dimension, given that this cost depends on the size of the operation. Therefore, liquidity effects are unambiguos only when we observe a spread increase (decrease) and a simultaneous depth decrease (increase), where depth is the number of shares available at each side of the market.

Somehow surprisingly, most papers analyzing the behavior of liquidity throughout the day or week have just studied the relative quoted spread or the relative effective spread, without considering the effects of trade size. Important exceptions are Lee, Mucklow and Ready (1993), Lin, Sanger and Booth (1995) and Pascual, Escribano and Tapia (2000). In any case, these papers are based on NYSE firms in which the role of the specialist proving liquidity is a key characteristic of the market.

This paper proposes and estimates a single measure of liquidity which is just an increasing function relating bid-ask spreads with size. It represents the cost of simultaneously buying and selling a given amount of shares. This function will be called the *liquidity function*, and it is developed in the context of a continuous auction system driven by orders. In other words, we exploit the opportunities provided by a continuous stock exchange market in which liquidity is provided by an electronic open limit order book. These order driven trading systems are employed in the Tokyo Stock Exchange, the Paris Bourse, the Toronto Stock Exchange, and the Spanish Stock Market among others.

These markets, provided that data are available, are particularly well suited to study liquidity by considering both the price and the quantity dimension as it should be done. In particular, we have the complete limit order book for July 1999 for five stocks of different market value trading in the Spanish continuous auction exchange. As in the paper by Biais, Hillion and Spatt (1995), and De Jong, Nijman and Röell (1996) for the Paris Bourse, we have the whole record of the limit order quantity at the five best prices on both the bid and the ask side of the market. However, the objective of their papers is very different from ours. We analyze the temporal intraday behavior of the liquidity function we developed, and the cross-sectional differences among five stocks with five alternative levels of market capitalization. Therefore, the availability of the five levels of prices and their corresponding quantities of the order book allows us to fully understand and describe liquidity as a function of the number of shares.

It should be clear that we do not employ transaction prices to analyze our measure of liquidity costs. Rather, the impact of private information attributable to adverse selection, as well as the competing different opinions among liquidity providers, originates the innovations occurred in the limit order book.

The only paper analyzing the intraday behavior of the limit order spread is due to Chung, Van Ness and Van Ness (1999). They argue that a relevant portion of the bid-ask quotes of market makers in the NYSE reflects the interest of limit order traders, so that they study the intraday patter of bid-ask spreads that originate from the limit order book.. Given that they just have the best available prices at each side of the market, they employ the usual measure of the bid-ask spread as a measure of liquidity. Our approach is more general and, very importantly, it employs the complete limit order book to obtain a much more precise measure of liquidity.

Next section describes the data employed in our analysis, the liquidity function is presented in Section 3 of the paper, while the empirical results are reported in Sections 4 and 5. Finally, we summarize our results and provide some conclusions in Section 6.

2. Data

The open limit order book contains information about the five best levels of prices of selling and buying orders over all assets in each instant. For each of these levels and for each market side we have information on the best price, volume of shares outstanding (depth) and number of orders which supports such volume. When a modification on any of these variables occurs, the limit order book shows us the new values of the variables, while the time stamps indicates exactly the time of this change (approximated by tenths of a second).

In order to consider a wide range of the market, we analyze the behavior of five alternative stocks chosen according to its market capitalization. These assets are all included in the Spanish IBEX-35 market index. The IBEX-35 is a value-weighted index comprising the 35 most frequently traded Spanish stocks of the continuous market. At the end of June 1999, all stocks comprising the index were classified into five portfolios according to its market value. The largest stock in each of the five size-sorted portfolios were finally chosen. Following this criterium, TELEFONICA [TEF] (which represents 20,46% of the IBEX-35 index), GAS NATURAL [CTG] (4,32), ACESA [ACE]

(1,24), ACERINOX [ACX] (0,68) and TELEPIZZA [TPZ] (0,44) were selected. Our sample period covers all trading days of July 1999.

The database has been checked looking for errors. Specifically, some observations where the bid price was greater than the ask has been removed from the sample (these errors were always found at the very beginning of the day). Thus for each modification in the order book we have 30 variables, six for each level (three on the buy side and three on the sell side) and the time of the change. The final number of observations (changes in the limit order book) during July 1999 were for each stock as follows: TELEFONICA, 86937; GAS NATURAL, 22823; ACESA, 12109; ACERINOX, 9603; and TELEPIZZA, 30471.

3. The Liquidity Function

As pointed out by De Jong, Nijman and Röell (1996), the trading mechanism operating in markets driven by orders can be formally described by the ideal electronic open limit order book framework proposed by Glosten (1994). This author presents a theoretical model of price revisions due to the information conveyed by trading throughout the limit order book mechanism. This is the framework in which our liquidity cost function is estimated. Glosten develops both average and marginal price functions from the point of view of the agent providing liquidity. Alternatively, we may understand these functions as revenue functions. Blanco (1999) discusses similar functions, and shows that what he calls the *supply function* (equivalent to Glosten´s average revenue function) is constant (and equal to the first level of prices) for the number of shares less or equal to the volume of the first level, and increasing and concave for a greater number of shares, with a different concavity for the volume correspondig to the remainder levels. On the other hand, the *demand function* is first constant, and then decreasing and convex, with also a different convexity for the volume associated with other levels.

We also employ the above framework by noting that our liquidity function can be derived using the bid and ask prices available at each of the five levels of the limit order book, and their corresponding volumes or depth.

Contrary to the perspective adopted by either Glosten or Blanco, our supply function is defined from the point of view of the investors willing to buy at the price shown in the limit order book. Hence, we define the *average cost function* (AC) as the unit cost of buying a determined volumen of shares:

$$AC(n) = \frac{\sum_{i=1}^{n} P_{ask}(i)}{n} \qquad (1)$$

where $P_{ask}(i)$ is the price investors should pay for the $i^{\text{-th}}$ share, and n is the number of shares they want to buy. Say that there are three levels of ask prices and their corresponding accumulated quantities or total available shares at those prices: $P_{a1} < P_{a2} < P_{a3}$, and the accumulated quantities $Q_{a1} < Q_{a2} < Q_{a3}$. The average cost function would be given by P_{a1} if $n < Q_{a1}$; $[P_{a1}Q_{a1} + P_{a2}(n - Q_{a1})]/n$ if $Q_{a1} \le n \le Q_{a2}$, and finally it would given by $[P_{a1}Q_{a1} + P_{a2}(Q_{a2} - Q_{a1})] + P_{a3}(n - Q_{a2})/n$ if $Q_{a2} \le n \le Q_{a3}$. It can be shown that this is an increasing and (step-wise) concave function after the shares available at the first level of prices.

From the other side of the market, we define the *average revenue function* (AR) as the unit revenue of selling a determined volume of shares:

$$AR(n) = \frac{\sum_{i=1}^{n} P_{bid}(i)}{n} \qquad (2)$$

where $P_{bid}(i)$ is the price investors would receive for the $i\text{-}^{th}$ share and n is the number of assets they want to sell. Again, it can be shown that this function is constant (and equal to the first level of prices) for the number of shares less or equal to the volume of the first level, and decreasing and (step-wise) convex for greater number of shares.

We are now in a position of defining the *liquidity function* as a new measure of liquidity. It measures the *relative* costs of buying and selling simultaneously a given number of shares:

$$L(n) = \frac{AC(n) - AR(n)}{V^*} \tag{3}$$

where V* is the asset *true* value defined as:

$$V^* = \frac{\sum_{j=1}^{5} \{[P_{ask}(j) x Q_{ask}(j)] + [P_{bid}(j) x Q_{bid}(j)]\}}{\sum_{j=1}^{5} [Q_{ask}(j) + Q_{bid}(j)]} \tag{4}$$

where $Q_{ask}(j)$ is the the number of available selling shares at the j-th level, while $Q_{bid}(j)$ is the the number of available buying shares at the j-th level.

As before, it can be shown that the liquidity function is constant for a volume less or equal than the lowest number of shares at either side of the market, and increasing at larger operating sizes.

Blanco (1999) also proposes a similar measure, where the true value is just the midpoint of the average cost and revenue functions for each number of shares. However, since the spread needs not be symmetric around the true value of the stock, it does not seem to be correct simply use the midpoint of the spread as the market price. Moreover, it should be noticed that our definition of the stock true value is unique independently of the number of shares, whereas this is not the case in Blanco´s definition.

Our definition allows us to distinguish each market side. In particular, the relative liquidity cost of buying a given number of shares (n) is defined as:

$$LB(n) = \frac{AC(n) - V^*}{V^*} \tag{5}$$

and the relative liquidity cost of selling a determined number of shares as:

$$LS(n) = \frac{V^* - AR(n)}{V^*} \quad (6)$$

It should be pointed out that both functions are increasing in the number of shares.

Moroever,

$$L(n) = LB(n) + LS(n) \quad (7)$$

The liquidity function given by equation (3) completely characterized the cost of liquidity of any given asset. It does not suffer from the usual ambiguities related to either the bid-ask spread or depth when they are considered separately. With a single measure, we are able to capture all dimensions associated with liquidity costs. Its estimation, as we explained in the next section of the paper, employs a superior set of information than the more traditional measures of liquidity. All information available in the open limit order book is necessary to calculate equation (3). This implies that our measure is particularly well suited for markets driven by orders.

4. Empirical results: Some preliminary evidence

In the empirical results we report below, and in order to allow fair comparisons between different moments of the day and stocks, it was decided to normalize the volumen of shares in each liquidity function by the total number of shares in the limit order book at the five levels. Thus, the horizontal axis of the liquidity functions we estimate measures the percentage of shares over the total limit order book instead of the number of shares. This implies that we provide the cost of liquidity in the sense of knowing the cost of buying and selling simultaneously a given percentage of the limit order book. It must be noted that higher percentages implies to move from the first levels of the book to higher levels where the conditions at each side of the market are worst. Of course, as expected, this indicates that the liquidity functions we report are always increasing.

Table 1 contains the average cost of liquidity for each stock in the sample, and it is obtained taking into account all instants in which there is a new entry in the open limit order book. It should be noted that TEF, the largest stock in the Spanish continuous market, has 86937 entries in the book during the month. However, the number of entries is not directly related to market capitalization. TPZ, the smallest stock in our sample, has 30471 entries in the book, which is the second largest number among the stocks in our sample. The average cost of liquidity is reported for five representative percentages of the book for each stock available. Table 1 also contains the average relative bid-ask spread for each of the five percentages, and the average depth.

As expected, the average cost of liquidity is increasing in the percentage of the book considered. This of course implies that it becomes more expensive to buy and sell simultaneously a higher percentage of the book. Moreover, TEF, the largest stock in the sample is also the most liquid asset independently of the percentage of the book we take. Similarly, TPZ, the smallest stock is also the less liquid asset for all percentage levels. The remaining stocks do not keep a direct relationship between market value and the cost of liquidity. In any case, their liquidity costs, for a given percentage of the book, are quite similar. It should also be noted that, for all five stocks, the percentage increase in liquidity costs between the 1% and 25% of the book tends to be very similar to the percentage increase between 25% and 100%. This suggests that the increase in liquidity costs changes very rapidly once trading moves from the first percentage level.

It is interesting to point out that the ranking of liquidity within each percentage level of the book is practically the same we would obtain by just observing the relative bid-ask spread. However, it is important to note that, on average, the relative bid-ask spread systematically overvalues the true cost of liquidity given by our measure. It should be recalled that the relative bid-ask spread is the cost of simultaneously buying and selling one unit of the stock. Given that the true cost of liquidity is increasing in size, one should expect the relative bid-ask spread to overvalue the true liquidity cost even for the one percentage level reported in our work. This is actually the case.

Generally speaking, average depth provides similar information to the previous two measures of liquidity. However, TPZ presents an unusually large number of shares available which is probably related to changes in the ownership composition experienced by this company in July 1999.

Table 2 reports the average cost of buying and selling a given percentage of the book during July 1999 for our five companies. As implied by expression (7), both figures add to the total average cost of liquidity provided by Table 1. It might be pointed out that, in this sample, the (liquidity) cost of buying is higher than the (liquidity) cost of selling. This is probably associated with the declining market during July 1999. Of course, market conditions should determined whether is more expensive in terms of liquidity cost to buy or to sell a given percentage of the book.

Initially, we construct the liquidity functions for each stock at every instant in which a modification in the limit order book is observed. It would be not practical however to report and perform statistical analysis with all available instants. Hence, we summarize the results by taking the mean of the normalized liquidity function for each quarter of an hour. If there are not modifications in the limit order book during a given quarter, we take the values of the last instant in the previous quarter.

Figure 1 shows our liquidity functions calculated according to expression (3) for each of the five stocks in our sample. As mentioned above, they are constructed as percentage of the book, and they are reported for every fifteen minutes. Each point on the graph indicates the cost of buying and selling simultaneously a given percentage of the book at a single quarter of an hour during July 1999.

Figure 1 confirms that the cost of liquidity is increasing in the number of shares, and that the behavior of the cost does not remain constant either throughout the day, or accross the stocks with different market values. In the case of TEF, the largest Spanish company traded in the stock exchange, there seems to be a slight evidence of higher liquidity costs at the beginning of the day, and particularly for high percentages of the book. It is not clear that there exists, generally speaking, the typical intraday U-shaped pattern found by McInish and Wood (1992), Lin, Sanger and Booth (1995), Chung, Van Ness and Van Ness (1999), or Pascual, Escribano and Tapia (2000).

For mid-market values companies like CTG and ACE, however, there seems to be a clearer evidence of a U-shaped for percentages higher than 25% of the book. ACX presents a rather clear (reversed) J-shaped pattern, and TPZ seems to have a decreasing cost of liquidity at the end of the day for all percentages of the book.

Figure 2 contains the same evidence but just reporting five alternative percentage levels of the book. The previously reported patterns are clearer appreciated now. A general pattern seems to emerge from the results. For ACE , CTG and ACX, there seems to exist evidence of a U-shaped or rather a (reversed) J-shaped intraday pattern in the cost of liquidity, but this seems to be especially true for high percentages of the limit order book. For TEF and TPZ the cost of liquidity is higher at the beginning of the day, but it is difficult to assess its relevance at the end of the day, although it becomes negative for TPZ. Formal tests on the intraday seasonality behavior of the liquidity cost will be performed later in the paper. In any case, whenever the J-shaped pattern is observed, it seems to be stronger at the highest percentage levels of the book. It is important to emphasize that previous empirical work has not been able to adduce this issue appropriately. Previous analysis has been carried out by taking account just the relative bid-ask spread.

Finally, Figure 3 presents the liquidity function estimated by equation (3) for all five companies at a given quarter of an hour, and for all percentages of the book. The first graph displays the liquidity cost as a function of the percentage of the book at 10:15 (beginning of the day), while the other two contain the liquidity function at 14:00 (middle of the day) and 17:00 (end of the day) respectively.

As expected, liquidity functions are increasing in the percentage of the book. At the beginning of the day, and almost independently of the percentage of the book considered, the cost of liquidity is higher the lower the market value of the company. However, and this is also true for the cost of liquidity at the end of the day, there exists some chages in the cost of liquidity accross companies relative to its market value. TPZ is not the less liquid company at either 10:15 or 17:00. However, this company is the less liquid asset for the rest of the fifteen minute intervals available.

Between 10:30 and 11:15, and independently of the percentage of the book, the largest the company the lower the cost of liquidity. Between 11:30 and 16:45, the same result is obtained except for ACX which becomes increasingly more liquid relative to other companies in the sample. In general, therefore, it is not true that the largest market value, the more liquid the company becomes. In any case, it should be noted that our measure is able to compare the cost of liquidity among companies for a given time of the day and a given percentage of the book or volume. This is a very important result.

Moreover, we know that the cost of liquidity as measured by the high of the vertical axis indicates the cost of buying and selling simultaneously a given percentage of the book. This is the concept emphasized in expression (3). However, it should be noted that our measure is able to incorporate another dimension of liquidity. The slope of the functions reported in Figure 3 suggest the variation in volume needed to move the spread differential. At the buy side of the market, the slope indicates how much volume is needed to move the ask prices relative to the true value of the asset. The reasoning would also be valid at the selling side of the market. It is very interesting to note that the empirical results regarding both the slope and the high dimension of our measure are consistent. We observe how the difference in the cost of liquidity becomes increasingly higher the higher is the percentage of the book considered. This is a consequence of the highest slope for the less liquid companies at increasingly larger percentage levels of the book.

5. Empirical results: The seasonal behavior of the liquidity costs

In order to interpret our results, it should be taken into account that our framework, as in Glosten (1994), is motivated by noting that each order is initiated an impatient trader who wants his order to be executed againts the limit orders available at different prices along the book. Only information derived from the book is used in calculating expression (3). In this context, in principle, limit orders providers must just be compensated for information costs. Accordingly, any new entry in the book conveys information which is exploited by our measure. In particular, a new entry in the book is buyer initiated when the innovation in the limit order book conveys good news about the fundamental value of the stock. Alternatively, it is seller initiated when the entrance in the book corresponds with bad news for the stock. We may conclude that any entry implies good news when either one of the following four cases occurs:

- whenever there exists a new order that improves the best bid price available
- any new entrance in price at the ask side which does not improve the best ask price
- any order at the ask side which is eliminated from the book

- any transaction at the ask price (this case cannot be distinguished from any order at the ask side and at the best level which is eliminated from the book)

On the other hand, bad news occur when either one of the following four cases occurs:

- whenever there exists a new order that improves the best ask price available
- any new entrance in price at the bid side which does not improve the best bid price
- any order at the bid side which is eliminated from the book
- any transaction at the bid price (this case cannot be distinguished from any order at the bid side and at the best level which is eliminated from the book)

Therefore, it is just the arrival of either good (buyer initiated move) or bad news (seller initiated move) which is analyzed in this paper. New information is completely linked to any change observed in the open limit order book. Any new entrance in the book is interpreted as the source of new information about the value of the stock, and consequently the interpretation of the results must be associated with information costs.

Once the general context in which our measure should be interpreted is explained, this section studies the intraday seasonal behavior of our liquidity cost measure, and therefore it analyzes the seasonal behavior of information costs in a order driven market.

We first consider each graph in Figure 2 from a global perspective. This means that the first regressions performed below formally tests the general behavior observed in each of the five graphs of Figure 2, instead of analyzing the seasonal behavior of the information costs separately at each of the five percentage levels of the book reported. In order to capture this global perspective within each asset, the following GLS regression is run:

$$L_s = \alpha + \sum_{\substack{t=1 \\ t \neq 14}}^{28} \beta_t DHt_s + \sum_{i=2}^{5} \delta_i DBi_s + u_s \tag{8}$$

where s represents both the level of the book, i = 1, . . , 5, and the fifteen minutes time interval, t = 1, . . , 28. Each regression is performed for each of the five assets separately, and therefore has s = 1, . . , 3080 observations (22 days x 28 time intervals x 5 levels). DHt_s (for t = 1 to 28, $t \neq 14$) are dummy variables that take the value of 1 for the t^{th} time interval of the session and zero otherwise. DBi_s (for i = 2, . . , 5) are dummy variables which equal 1 for the corresponding level of the book and zero otherwise. It must be noted that, α captures the average liquidity cost at the 1% level of the book and, simultaneously, at the 14^{th} time interval between 1:15 pm and 1:30 pm which corresponds to the middle of the day. The estimates of the regression coefficients representes the differences in liquidity costs relative to the average cost measured by α. The weighted matrix used to obtain the GLS estimator is the Newey-West matrix with one lag[1].

Table 3 contains the results. As expected, the coefficients associated to the alternative percentages of the book are always positive and increasing independently of the asset considered. At the same time, relative to the cost at 14^{th} time interval, liquidity costs for ACE, ACX and CTG (the mid-sized companies) are higher both at the beginning and at the end of the day. The differences are always higher at the beginning of the day than at the end of day. This suggest that, globally, there exists evidence of a significant (reversed) J-shaped for information costs as measured by our liquidity cost function. A less clear evidence is reported for TEF, the largest company of the exchange, while TPZ presents a significant average decline in liquidity costs at the end of the day relative to the mid-day cost.

In Table 4, we analyze the seasonal behavior of the liquidity costs for each asset, and for each percentage level of the book separately. This allows us to tests whether the seasonal behavior of information costs are different depending upon high or low percentages of the book are traded. This is an important issue, and to the best of our knowledge it has not been previously studied.

For a given percentage of the book , the regressions we run now are of the following form:

[1] Statistical tests were performed to decide the number of lags included in the regressions.

$$L_s = \alpha + \sum_{\substack{t=1 \\ t \neq 14}}^{28} \beta_t DHt_s + u_s \tag{9}$$

where s represents the fifteen minutes time interval, t = 1, . . , 28. Each regression is performed for each of the five assets separately, and therefore has s = 1, . . , 616 observations (22 days x 28 time intervals). As before, DHt_s (for t = 1 to 28, t ≠ 14) are dummy variables that take the value of 1 for the t^{th} time interval of the session and zero otherwise. Then, for a given percentage of the book and a given asset, α captures the average liquidity cost at the 14^{th} time interval which, once again, corresponds to the middle of the day. The estimates of the regression coefficients representes the differences in liquidity costs relative to the average cost at the time interval between 1:15 pm and 1:30 pm.

The results are reported in 5 panels corresponding to our five companies in the sample. For ACE and CTG a significant (reversed) J-shaped is found in all percentage levels of the book. Independently of the percentage of the book traded, a similar seasonal behavior is obtained. However, it should be noted that a quite striking pattern is observed. The J-shaped behavior is much stronger for high perecentages levels than for low percentage levels. This can be seen by analyzing the magnitudes of the regression estimates, but also by noting the adjusted R^2, which becomes higher the higher the percentage of the book traded.

For the three other companies, a similar pattern is obtained although the differences relative to the mid-day cost are only significant at the beginning of the day. In any case, the magnitudes of the coefficients are always higher for high percentage levels of the book. Again, a stronger seasonal behavior seems to exist when trading represents a sufficiently high percentage of the book.

This finding may be summarized by pointing out that information costs as measured by our liquidity cost function is particularly high at the beginning of the day with a (reversed) J-shaped behavior especially relevant for high percentage levels of the book.

In order to discuss this finding, it should be pointed out that the actual traded volume represents, on average, approximately 4% of the volume available at each instant in the book. It is also important to recall that the level of trading activity for the five companies in our sample indeed presents a U-shaped pattern. In Figure 4, we report the intraday average number of transactions for all five companies in our sample, and for every quarter during July 1999. It is clear that at the beginning and at the end of the day, the activity of the market as measured by the number of transactions increases. The same U-shaped pattern is found when activity is measured as the traded volume accumulated during the 28 intervals of fifteen minutes[2].

If we accept that the cost of liquidity is quite higher at the beginning of the day and slightly higher at the end of the day, but this pattern is especially strong for high percentages of the limit order book, and at the same time actual trading activity also increases during the beginning and end of the trading period, we should be able to respond why the cost of liquidity increases with trade size (for sufficiently high volumes). This finding is consistent with the model of Easley and O'Hara (1987) in which this increase is explained by adverse selection. As they point out, high volume introduces an adverse selection problem given that informed traders, whenever they want to trade, prefer to trade large amount of shares at any particular price. If an individual would be willing to trade a large amount of shares, or a large percentage of the book, it may suggest that the agent is an informed trader. These large trading conveys more information to the market. In other words, the adverse selection component of the liquidity cost increases with size. Hence, the finding of the J-shaped pattern at high percentages of the book is consistent with arguments related with information asymmetries in the market.

On the other hand, it should be recalled that at low percentages of the book, the J-shaped pattern tends to disappear. However, as mentioned above, we know that trading activity do have the U-shaped intraday pattern. This is inconsistent with an explanation based solely on adverse selection arguments. At low percentage levels of the book, a compensating explanation of the adverse selection argument should be employed.

[2] A similar pattern is found for all five companies at the individual level.

We should have a model in which high levels of activity tends to reduce liquidity costs. This reduction would compensate the higher adverse selection related to more trading activity as models based on information asymmetries postulate. Harris and Raviv (1993) suggest a model in which agents receive the same information. However, these agents differ in the way in which they understand this common information. Volume shocks are simply a consequence of the lack of agreement among participants in the market. This context implies that higher volume should be related to liquidity providers sending limit orders in both sides of the market as a result of differences on opinion. This may tend to reduce the cost of liquidity.

Our suggestion is that, at low percentages levels of the book, both explanations are taking place simultaneously. There exists more activity so that adverse selection plays a role, but it is also the case that, at these volumes, there also exists more competition among liquidity providers reducing the cost of liquidity, and compensating the adverse selection component.

6. Conclusions

This paper has proposed and estimated a new measure of liquidity for markets driven by orders. The full availability of the limit order book is needed. However, once these data are observed, a very useful measure of liquidity is easily estimated. This single measure completely characterized the cost of liquidity. This is a very important issue, since it avoids the traditional ambiguities confronted by researchers when using either the relative bid-ask spread or depth. Formal tests on the seasonal behavior of the liquidity cost calculated in this paper suggest that information costs associated with adverse selection, but also competing interpretation about the arriving information are needed to explain the seasonal behavior of liquidity costs. Future research should employ transaction prices to investigate the components of the new measure of liquidity costs studied in this paper.

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Table 1

Average Liquidity Cost, Relative Spread and Depth
for Five Percentages of the Book

The liquidity cost represents the costs of buying and selling simultaneously a given amount of shares. It is given by $L(n) = [AC(n) - AR(n)]/V^*$, where AC(n) is the average cost, AR is the average revenue, and where V* approximates the true value of the asset. In the table below, the average of the liquidity cost over all entries in the open limit order book during July 1999, and for each stock available in the sample is calculated for five representative percentages of the book. The relative spread is just $(P_a - P_b)/(P_a + P_b/2)$. Again, it is obtained as the average over the whole sample period for each stock in our cross-sectional sample. Depth is also given as the corresponding average for all trading days during July 1999. Both are calculated within each of the five percentages of the book employed in the table.

Book (%)	ACE (12109)	ACX (9603)	CTG (22823)	TPZ (30471)	TEF (86937)
		Panel A: Average Liquidity cost			
1%	0.00286	0.00266	0.00295	0.00359	0.00074
25%	0.00471	0.00437	0.00438	0.00726	0.00136
50%	0.00613	0.00573	0.00562	0.00997	0.00184
75%	0.00738	0.00698	0.00674	0.01224	0.00207
100%	0.00855	0.00822	0.00783	0.01436	0.00267
		Panel B: Average Relative Spread			
1%	0.00295	0.00273	0.00302	0.00381	0.00078
25%	0.00630	0.00589	0.00574	0.01032	0.00190
50%	0.00871	0.00829	0.00793	0.01476	0.00273
75%	0.01096	0.01067	0.00999	0.01873	0.00349
100%	0.01334	0.01342	0.01210	0.02251	0.00434
		Panel C: Average Depth			
1%	347.10	129.24	113.88	1104.76	594.53
25%	8677.46	3231.05	2847.00	27618.97	14863.30
50%	17354.93	6462.10	5693.99	55237.95	29726.61
75%	26032.39	9693.15	8540.99	82856.92	44589.91
100%	34709.86	12942.19	11387.99	110475.89	59453.21

Table 2

Average Liquidity Cost for both Sides of the Market and for Five Percentages of the Book.

The liquidity cost of buying a given number of shares is given by $LB(n) = [AC(n) - V^*]/V^*$, where AC(n) is the average cost, and V* approximates the true value of the asset. The liquidity cost of selling a given number of shares is given by $LS(n) = [V^* - AR(n)]/V^*$, where AR(n) is the average revenue. In the table below, the average of the liquidity cost of buying and selling over all entries in the open limit order book during July 1999, and for each stock available in the sample is calculated for five representative percentages of the book.

Book	ACE	ACX	CTG	TPZ	TEF
Panel A: Buy liquidity cost					
1%	0.00157	0.00163	0.00159	0.00238	0.00036
25%	0.00250	0.00254	0.00226	0.00417	0.00066
50%	0.00324	0.00320	0.00293	0.00556	0.00091
75%	0.00391	0.00376	0.00356	0.00676	0.00113
100%	0.00456	0.00429	0.00418	0.00787	0.00135
Panel B: Sell liquidity cost					
1%	0.00129	0.00103	0.00137	0.00121	0.00038
25%	0.00221	0.00183	0.00212	0.00309	0.00070
50%	0.00289	0.00253	0.00269	0.00441	0.00093
75%	0.00346	0.00322	0.00318	0.00548	0.00937
100%	0.00399	0.00393	0.00365	0.00649	0.00133

Table 3
The liquidity function: Seasonal behavior

We estimate a separate GLS regression for each asset using the Newey-West covariance matrix adjusting for serially correlated and heteroskedastic errors:

$$L_s = \alpha + \sum_{\substack{t=1 \\ t\neq 14}}^{28} \beta_t DHt_s + \sum_{i=2}^{5} \delta_i DBi_s + u_s$$

where s represents both the level of the book, i = 1, . . , 5, and the fifteen minutes time interval, t = 1, . . , 28. Each regression is performed for each of the five assets separately, and therefore has s = 1, . . , 3080 observations (22 days x 28 time intervals x 5 levels). DHt_s (for t = 1 to 28, $t \neq 14$) are dummy variables that take the value of 1 for the t^{th} time interval of the session and zero otherwise. Dbi (for i = 2, . . , 5) are dummy variables which equal 1 for the corresponding level of the book and zero otherwise. It must be noted that, α captures the average liquidity cost at the 1% level of the book and, simultaneously, at the 14^{th} time interval between 1:15 pm and 1:30 pm which corresponds to the middle of the day. The estimates of the regression coefficients representes the differences in liquidity costs relative to the average cost measured by α. * is significant at 5%, ** is significant at 10%. The Newey-West covariance matrix with one lag is employed.

STOCKS	ACE		ACX		CTG		TEF		TPZ	
Constant	0,00160568	*	0,0019041	*	0,00187571	*	0,00056216	*	0,00360894	*
25% Level	0,00170951	*	0,0016821	*	0,00132675	*	0,00056551	*	0,00354274	*
50% Level	0,003065	*	0,00303425	*	0,00249397	*	0,00101028	*	0,00620374	*
75% Level	0,00426497	*	0,00428271	*	0,00356217	*	0,00123755	*	0,00843155	*
100% Level	0,0053856	*	0,00548906	*	0,00460642	*	0,00178563	*	0,01051837	*
10:00-10:15	0,00407453	*	0,00506549	*	0,00329293	*	0,00062034	*	0,00196847	*
10:15-10:30	0,00217785	*	0,00286026	*	0,00177027	*	0,00030039	*	0,00082418	*
10:30-10:45	0,00149479	*	0,0024545	*	0,0012939	*	0,00020519	**	0,00015349	
10:45-11:00	0,00127158	*	0,0020728	*	0,00134765	*	0,00016641		1,0624E-05	
11:00-11:15	0,00114438	*	0,00188301	*	0,00078805	*	0,00012027		0,00014313	
11:15-11:30	0,00127341	*	0,00082932	*	0,00077396	*	0,00016394		0,00036556	**
11:30-11:45	0,00078978	*	0,00070085	*	0,00021143		-1,4767E-05		-9,856E-06	
11:45-12:00	0,00051994	*	0,00034352		0,00050386	*	-3,5588E-05		-0,00041033	**
12:00-12:15	0,00040062	*	0,00048138		0,00046091	*	8,6108E-05		-0,00054935	*
12:15-12:30	0,00012798		0,0001261		0,00039812	*	0,00016985		-0,00022195	
12:30-12:45	7,6073E-05		3,9628E-05		0,00019119		1,0306E-05		-0,00004886	
12:45-13:00	-2,6851E-05		-0,00027196		-1,1758E-05		3,9618E-05		0,00022002	
13:00-13:15	-5,3041E-05		0,00020014		0,00040958	*	7,1288E-05		0,00014427	
13:30-13:45	6,9116E-05		3,0548E-05		0,00028909		-0,00011113		-2,367E-06	
13:45-14:00	0,00042634		-0,00011946		7,463E-06		-2,9213E-05		-0,00060412	*
14:00-14:15	0,00015587		-0,00050232		0,00029938		-3,2266E-05		-0,00021456	
14:15-14:30	0,00036864	**	-0,00074934	*	0,00041269	**	4,9194E-05		3,832E-06	
14:30-14:45	0,00070504	*	-0,00064364	*	0,00067457	*	0,00016026		-0,00044389	**
14:45-15:00	0,00059635	*	-0,0007485	*	0,00081381	*	7,6385E-05		-9,4683E-05	
15:00-15:15	0,00065954	*	-0,00079424	*	0,0008363	*	8,0104E-05		-0,00032838	
15:15-15:30	0,00072372	*	-0,00040905		0,00040863	**	-2,6001E-05		-0,00056565	*
15:30-15:45	0,00066855	*	-4,6304E-05		0,00047744	*	0,00010143		-0,00058112	*
15:45-16:00	0,00091424	*	0,00029384		0,00076704	*	0,0001077		-0,00044669	**
16:00-16:15	0,00104775	*	0,00051844		0,0011827	*	0,00026951	*	0,00037698	
16:15-16:30	0,00104274	*	0,00060972	**	0,00114268	*	0,00027071	*	0,00027133	
16:30-16:45	0,00208591	*	0,00055089	**	0,00079657	*	0,00019368		-0,00037774	
16:45-17:00	0,00231501	*	0,00081716	*	0,00172408	*	0,00023899	**	-0,00127454	*
Adjusted R^2	0,523462		0,468399		0,451527		0,340767		0,789681	

Table 4

The liquidity function: Seasonal behavior for each company at alternative percentage levels of the book

We estimate a separate GLS regression for each asset and five alternative percentage levels of the book using the Newey-West covariance matrix adjusting for serially correlated and heteroskedastic errors:

$$L_s = \alpha + \sum_{\substack{t=1 \\ t \neq 14}}^{28} \beta_t DHt_s + u_s$$

where s represents the fifteen minutes time interval, t = 1, . . , 28. Each regression is performed for each of the five assets separately, and therefore has s = 1, . . , 616 observations (22 days x 28 time intervals). As before, DHt_s (for t = 1 to 28, t ≠ 14) are dummy variables that take the value of 1 for the t^{th} time interval of the session and zero otherwise. Then, for a given percentage of the book and a given asset, α captures the average liquidity cost at the 14^{th} time interval which corresponds to the middle of the day. The estimates of the regression coefficients representes the differences in liquidity costs relative to the average cost at the time interval between 1:15 pm and 1:30 pm. * is significant at 5%, ** is significant at 10%. Each panel shows the results from five regresions for each asset and five alternative percentage levels of the book with 1 lag autocorrelation structure in the Newey-West covariance matrix.

Panel A: ACE.										
Book Levels	1%		25%		50%		75%		100%	
Constant	0,002151655	*	0,003265859	*	0,004537485	*	0,005740666	*	0,006757796	*
10:00-10:15	0,002315541	*	0,003991672	*	0,004481808	*	0,004649572	*	0,004934051	*
10:15-10:30	0,001121467	*	0,001871198	*	0,002385774	*	0,002625443	*	0,002885341	*
10:30-10:45	0,000550613	**	0,001375083	*	0,00171331	*	0,001822428	*	0,002012503	*
10:45-11:00	0,000508014		0,001462243	*	0,001433409	*	0,001394901	*	0,001559313	*
11:00-11:15	0,000461024		0,001337956	*	0,00130013	*	0,001260432	*	0,001362362	*
11:15-11:30	0,000637871	**	0,001440726	*	0,001458025	*	0,001379269	*	0,001451174	*
11:30-11:45	0,000324046		0,000899267	*	0,000922942	*	0,000875764	**	0,000926864	**
11:45-12:00	0,000214123		0,000645318		0,000560727		0,000533591		0,000645949	
12:00-12:15	0,000117456		0,000480918		0,000510032		0,000429013		0,000465698	
12:15-12:30	-0,000171746		0,000181227		0,00022318		0,000155524		0,000251715	
12:30-12:45	-0,00024829		0,000113852		0,000122605		0,000149662		0,000242535	
12:45-13:00	-0,000165211		0,000148827		-0,000024896		-0,000101015		0,000008038	
13:00-13:15	-0,000021884		0,000119147		-0,000069915		-0,000187871		-0,00010468	
13:30-13:45	-0,000348381		6,04298E-05		0,000185464		0,000204543		0,000243522	
13:45-14:00	0,000157598		0,000340477		0,000497542		0,000511109		0,00062499	
14:00-14:15	-0,000187116		0,000220404		0,000251197		0,000197923		0,000296959	
14:15-14:30	-0,000062259		0,000509089		0,000499664		0,00042208		0,000474632	
14:30-14:45	0,000375459		0,000840605	**	0,000766917		0,000724213		0,000818022	
14:45-15:00	0,000352989		0,00063178		0,000598164		0,000619832		0,000778979	
15:00-15:15	0,000159525		0,000646523		0,000770065		0,000804306		0,000917272	
15:15-15:30	0,000336412		0,000689198		0,00085621		0,000831299		0,000905487	
15:30-15:45	0,00025512		0,000665848		0,000808715		0,000782923		0,000830122	
15:45-16:00	0,00028539		0,001084257	*	0,001108949	*	0,001032251	**	0,001060356	**
16:00-16:15	0,000381081		0,001139795	*	0,001219412	*	0,001221877	*	0,001276605	*
16:15-16:30	0,000394688		0,00122772	*	0,001217034	*	0,001139102	*	0,001235169	*
16:30-16:45	0,000880856	*	0,002070248	*	0,002348772	*	0,002485211	*	0,002644468	*
16:45-17:00	0,001138127	*	0,002237203	*	0,002633908	*	0,002726034	*	0,002839791	*
Adjusted R^2	0,080697		0,149985		0,158319		0,148627		0,13736	

Table 4

The liquidity function: Seasonal behavior for each company at alternative percentage levels of the book

(continuation)

Panel B: ACX.					
Book Levels	1%	25%	50%	75%	100%
Constant	0,002050337*	0,00367896 *	0,00488647 *	0,006091031*	0,00730181 *
10:00-10:15	0,003177456*	0,00415922 *	0,00501768 *	0,005973282*	0,00699978 *
10:15-10:30	0,001912184*	0,00249692 *	0,00290930 *	0,003208478*	0,00377442 *
10:30-10:45	0,001228469*	0,0022453 *	0,00269320 *	0,002857932*	0,00324748 *
10:45-11:00	0,001016437**	0,0016455 *	0,00222207 *	0,002585066*	0,00289484 *
11:00-11:15	0,001265976*	0,00178236 *	0,00199937 *	0,002151756*	0,00221560 *
11:15-11:30	0,000521698	0,00079008	0,00097614	0,000965258	0,00089341
11:30-11:45	0,000474347	0,00049076	0,00085220	0,000887527	0,00079941
11:45-12:00	0,000128132	0,0002190	0,00041334	0,000515977	0,00044103
12:00-12:15	0,000427898	0,00026241	0,00050708	0,000606312	0,00060320
12:15-12:30	0,000003628	0,00019729	0,00027977	0,000145878	0,00000394
12:30-12:45	-0,000109089	0,00003981	0,000159	0,000103946	0,00000426
12:45-13:00	-0,000374995	-0,00038243	-0,00024478	-0,000177102	-0,000180
13:00-13:15	0,000271753	0,00013036	0,00017781	0,000244167	0,00017662
13:30-13:45	0,000430968	-0,0000463	-0,00005455	-0,000083568	-0,0000937
13:45-14:00	0,000215702	-0,00024423	-0,00007357	-0,000159155	-0,0003360
14:00-14:15	-0,000219228	-0,00048667	-0,00048370	-0,0005727	-0,000749
14:15-14:30	-0,000356501	-0,00080360	-0,00075528	-0,000814952	-0,0010163
14:30-14:45	-0,000312799	-0,00066522	-0,00070608	-0,000695946	-0,0008381
14:45-15:00	-0,000180766	-0,0007326	-0,00091007	-0,000882234	-0,0010367
15:00-15:15	-0,000226317	-0,0006884	-0,00092383	-0,000994015	-0,0011385
15:15-15:30	-0,000021506	-0,00031853	-0,0003957	-0,000570498	-0,0007389
15:30-15:45	0,000123712	0,00006973	0,00002517	-0,000114562	-0,0003355
15:45-16:00	0,000155866	0,00039824	0,00040459	0,00034398	0,00016652
16:00-16:15	0,000330483	0,00057831	0,00070099	0,000581397	0,0004009
16:15-16:30	0,000466969	0,0006495	0,00073510	0,000652917	0,00054407
16:30-16:45	0,000539534	0,00051685	0,0006014	0,000579282	0,0005172
16:45-17:00	0,00060814	0,00069154	0,00091853	0,000936084	0,00093150
Adjusted R^2	0,154948	0,17444	0,18091	0,195478	0,22723

Table 4

The liquidity function: Seasonal behavior for each company at alternative percentage levels of the book

(continuation)

Panel C: CTG.										
Book Levels	1%		25%		50%		75%		100%	
Constant	0,002199005	*	0,003239267	*	0,004254545	*	0,005308531	*	0,006366488	*
10:00-10:15	0,00195477	*	0,002798729	*	0,003383941	*	0,003882155	*	0,004445069	*
10:15-10:30	0,000918053	*	0,0015552	*	0,001866284	*	0,002141448	*	0,002370341	*
10:30-10:45	0,000747112	*	0,001232193	*	0,001444645	*	0,001475607	*	0,001569935	*
10:45-11:00	0,000663566	**	0,001234707	*	0,00156814	*	0,001627537	*	0,001644281	*
11:00-11:15	0,000303629		0,000707204	**	0,000947284	*	0,000976081	**	0,001006025	**
11:15-11:30	0,000565885		0,000672155	**	0,000873812	*	0,000882194	**	0,000875762	**
11:30-11:45	0,000057714		0,000166356		0,000287068		0,000284005		0,000262009	
11:45-12:00	0,000244381		0,000477307		0,000625143		0,000615393		0,00055709	
12:00-12:15	0,000064057		0,000446504		0,000631023		0,00063039		0,000532571	
12:15-12:30	0,000160954		0,00048113		0,00055283		0,000475771		0,000319922	
12:30-12:45	0,000345367		0,000397562		0,000279096		0,000066715		-0,00013277	
12:45-13:00	0,000057976		0,000139168		6,43766E-05		-0,000069018		-0,00025129	
13:00-13:15	0,000117419		0,000391802		0,000502797		0,000571161		0,000464717	
13:30-13:45	0,000190074		0,000328285		0,000376941		0,000326451		0,000223687	
13:45-14:00	-0,00005293		7,0564E-06		7,98056E-05		0,000027595		-2,4211E-05	
14:00-14:15	0,000156505		0,000269517		0,00033732		0,000350723		0,00038285	
14:15-14:30	0,000248302		0,000370622		0,000476752		0,00047358		0,000494182	
14:30-14:45	0,000507243		0,00070444	**	0,00078119	**	0,000720704		0,000659275	
14:45-15:00	0,000624181		0,000791231	**	0,00092313	**	0,000900096		0,000830385	
15:00-15:15	0,000769039		0,000883805	**	0,000940812	**	0,000839324		0,000748507	
15:15-15:30	0,000421117		0,000447203		0,000436395		0,000385046		0,000353405	
15:30-15:45	0,000129359		0,000435932		0,000633029		0,000621002		0,000567858	
15:45-16:00	0,000353081		0,000755778	**	0,000965112	*	0,00093896	**	0,000822242	
16:00-16:15	0,000713286	**	0,001128907	*	0,001368228	*	0,00137995	*	0,001323148	*
16:15-16:30	0,00049822		0,001082374	*	0,001359707	*	0,001391369	*	0,001381721	*
16:30-16:45	0,000556666		0,000691679		0,000863142	**	0,000925671	**	0,00094568	
16:45-17:00	0,00089515	**	0,001634959	*	0,001918086	*	0,002044282	*	0,002127938	*
Adjusted R^2	0,032273		0,066031		0,077374		0,087471		0,104227	

Table 4

The liquidity function: Seasonal behavior for each company at alternative percentage levels of the book

(continuation)

Panel D: TEF										
Book Levels	1%		25%		50%		75%		100%	
Constant	0,000632133	*	0,001158603	*	0,00156626	*	0,001735708	*	0,002317086	*
10:00-10:15	0,000308819	*	0,000517495	*	0,000637299	*	0,000764822	*	0,000873259	*
10:15-10:30	0,000106068		0,000216778		0,00031585		0,000445796	**	0,000417476	
10:30-10:45	0,000077877		0,000165517		0,000240081		0,000288629		0,000253843	
10:45-11:00	0,000033451		0,000138985		0,000188355		0,000274633		0,000196622	
11:00-11:15	0,000011686		0,000075519		0,000129442		0,000239816		0,000144882	
11:15-11:30	0,000066711		0,00015442		0,000181092		0,000225321		0,000192134	
11:30-11:45	-0,00004639		-0,000032762		-0,00001039		0,000045857		-3,0148E-05	
11:45-12:00	-0,000042569		-0,000039547		-0,000046145		0,000004341		-5,4021E-05	
12:00-12:15	0,000056104		0,000055654		0,000089544		0,000150285		0,000078953	
12:15-12:30	0,00009087		0,000122629		0,000187717		0,000235557		0,000212458	
12:30-12:45	-0,000029299		0,000012435		0,000033593		0,000045114		-1,0311E-05	
12:45-13:00	-0,000011141		0,000039813		0,000063094		0,000075728		0,000030597	
13:00-13:15	0,000036383		0,000092839		0,0001061		0,000049357		0,00007176	
13:30-13:45	-0,000056975		-0,000093836		-0,000120551		-0,000124607		-0,00015969	
13:45-14:00	-0,000010388		-0,000044841		-0,000043977		0,000009716		-5,6572E-05	
14:00-14:15	-0,000022597		-0,000024951		-0,000036688		-0,000008805		-6,8288E-05	
14:15-14:30	-0,000027088		0,000019106		0,000058523		0,000130177		0,000065253	
14:30-14:45	0,00006003		0,000073883		0,000169297		0,000236923		0,000261167	
14:45-15:00	0,000000012		0,000002801		0,000053151		0,000202497		0,000123463	
15:00-15:15	0,000090464		0,000063153		0,000050033		0,000140253		0,000056619	
15:15-15:30	-0,000025425		-0,000066425		-0,000050167		0,000022699		-1,0689E-05	
15:30-15:45	0,000065794		0,000071222		0,000085929		0,000162245		0,000121943	
15:45-16:00	0,000061561		0,000076081		0,000119177		0,000138631		0,000143073	
16:00-16:15	0,00012329		0,000217687		0,000280832		0,000373848		0,000351884	
16:15-16:30	0,000148666		0,000205169		0,000278554		0,000365731		0,000355427	
16:30-16:45	0,000080282		0,000153535		0,000211427		0,000277655		0,000245484	
16:45-17:00	0,000147375		0,00021423		0,00025472		0,000272775		0,000305859	
Adjusted R^2	0,009677		-0,010203		-0,015571		-0,009813		-0,018428	

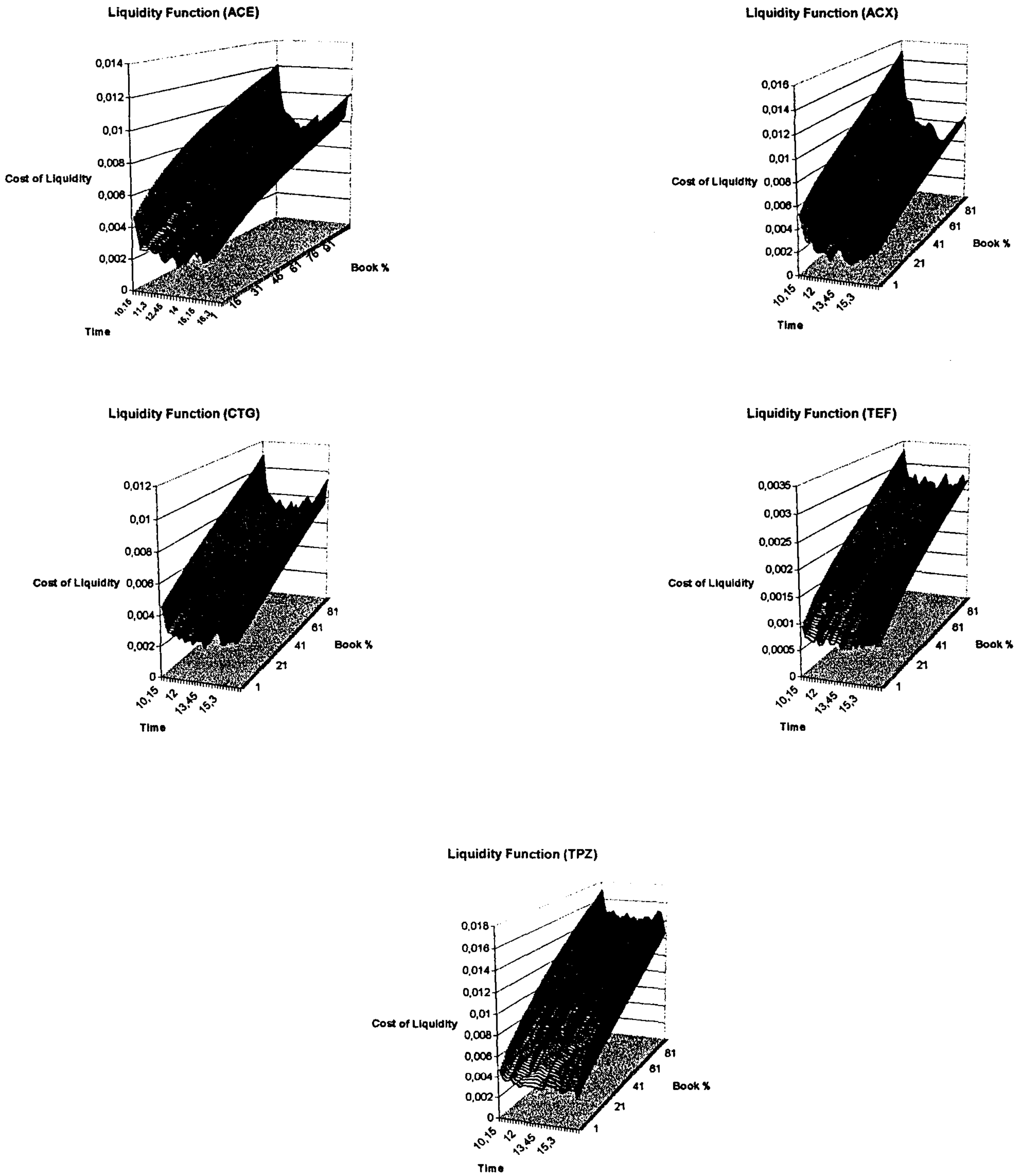
Table 4

The liquidity function: Seasonal behavior for each company at alternative percentage levels of the book

(continuation)

Panel E:TPZ.										
Book Levels	1%		25%		50%		75%		100%	
Constant	0,003371858	*	0,007138503	*	0,010011081	*	0,012153898	*	0,014065749	*
10:00-10:15	0,001322539	*	0,001764246	*	0,001930157	*	0,002183978	*	0,002641424	*
10:15-10:30	0,000599818	**	0,000815148		0,000688865		0,000869673		0,00114738	**
10:30-10:45	0,000345471		0,000210248		-0,000036013		0,000033578		0,000214162	
10:45-11:00	0,000103648		-0,000012106		-0,000201475		-0,00005336		0,000216412	
11:00-11:15	0,000430061		0,000271377		-0,000108566		-0,000102013		0,000224765	
11:15-11:30	0,000329289		0,000411991		0,000248489		0,00033092		0,000507132	
11:30-11:45	0,000110431		-0,000178784		-0,000156587		0,000003451		0,000172209	
11:45-12:00	-0,000286215		-0,000504967		-0,000646427		-0,000431666		-0,00018236	
12:00-12:15	-0,000065898		-0,000609899		-0,000822476		-0,000702566		-0,00054589	
12:15-12:30	0,000036645		-0,000332826		-0,000471405		-0,000251071		-9,1092E-05	
12:30-12:45	0,000165617		-0,000043578		-0,000167334		-0,000123757		-7,5249E-05	
12:45-13:00	0,00009151		0,00033062		0,000251222		0,000243167		0,000183584	
13:00-13:15	0,000159781		0,000351743		0,000149113		0,000049301		0,000011395	
13:30-13:45	0,000142832		0,00002987		-0,000103144		-0,0000883		0,000006905	
13:45-14:00	-0,000109456		-0,000487779		-0,000830945		-0,000878415	**	-0,00071399	
14:00-14:15	0,000390628		-0,000222089		-0,000588703		-0,00045869		-0,00019395	
14:15-14:30	0,000465821		0,000136742		-0,000245784		-0,000256604		-8,1019E-05	
14:30-14:45	0,000216386		-0,000392682		-0,000806973		-0,000750802		-0,0004854	
14:45-15:00	0,000271414		-0,000079386		-0,000348475		-0,000223708		-0,00009326	
15:00-15:15	-0,000002293		-0,000293565		-0,000555946		-0,000467416		-0,00032266	
15:15-15:30	0,000080241		-0,000615744		-0,000841701		-0,000781921		-0,00066911	
15:30-15:45	-0,000107046		-0,000397612		-0,000888252		-0,000850625		-0,00066205	
15:45-16:00	0,000060386		-0,000395809		-0,000676483		-0,000660493		-0,00056106	
16:00-16:15	0,000415021		0,000335626		0,000218435		0,000393229		0,000522597	
16:15-16:30	0,00007704		0,000263581		0,000244662		0,000351124		0,000420232	
16:30-16:45	0,0001262		-0,000417507		-0,000694012		-0,000578366		-0,00032504	
16:45-17:00	-0,000423853		-0,001260155	*	-0,0017878	*	-0,001666355	*	-0,00123455	*
Adjusted R^2	0,029866		0,037716		0,046762		0,045681		0,054638	

FIGURE 1



Liquidity Function (ACE)
Cost of Liquidity
Time
Book %
Liquidity Function (ACX)
Cost of Liquidity
Time
Book %
Liquidity Function (CTG)
Cost of Liquidity
Time
Book %
Liquidity Function (TEF)
Cost of Liquidity
Time
Book %
Liquidity Function (TPZ)
Cost of Liquidity
Time
Book %

FIGURE 2

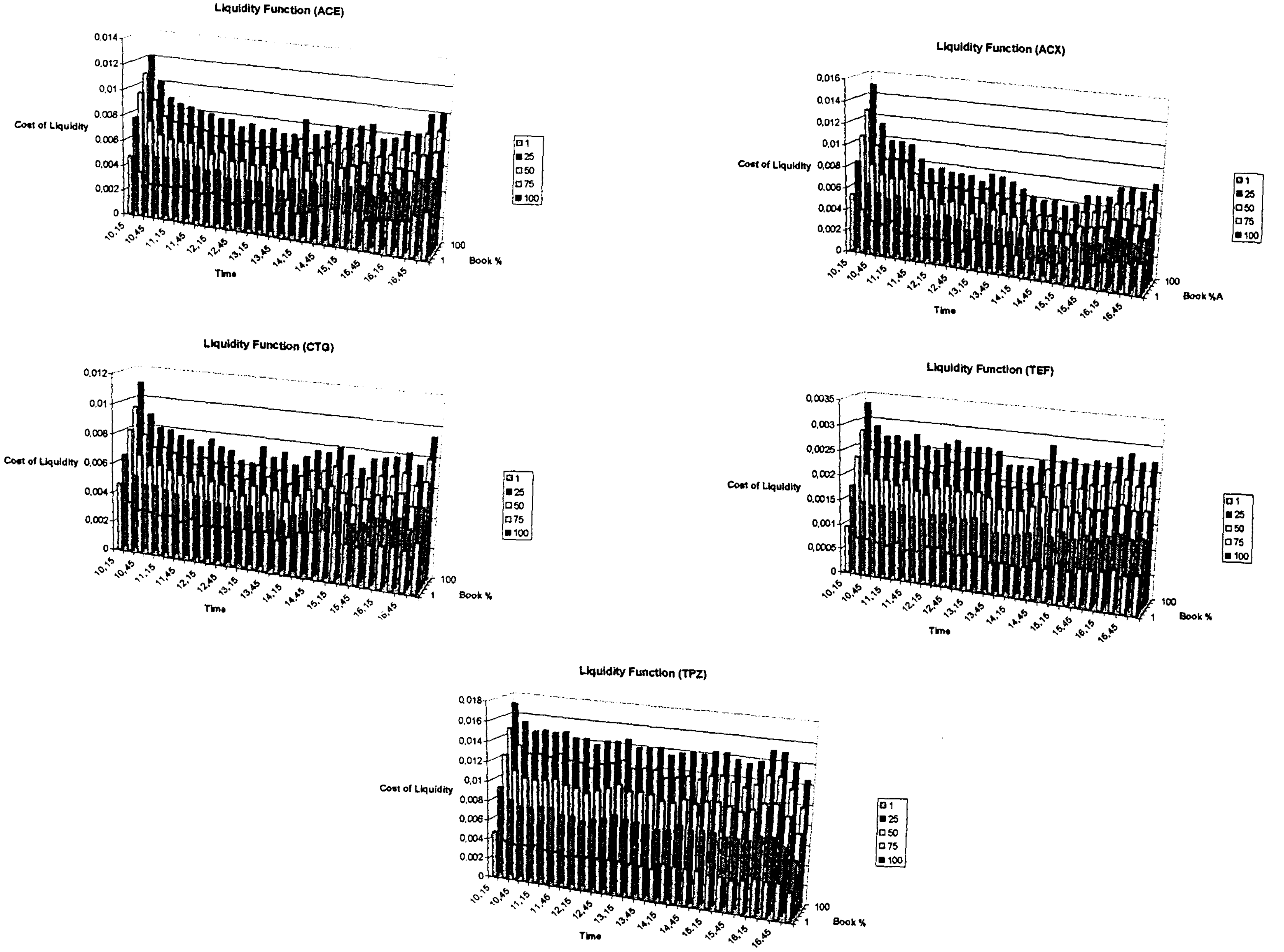

Liquidity Function (ACE)
Cost of Liquidity
Time
Book %
Liquidity Function (ACX)
Cost of Liquidity
Time
Book %A
Liquidity Function (CTG)
Cost of Liquidity
Time
Book %
Liquidity Function (TEF)
Cost of Liquidity
Time
Book %
Liquidity Function (TPZ)
Cost of Liquidity
Time
Book %
1
25
50
75
100

FIGURE 3

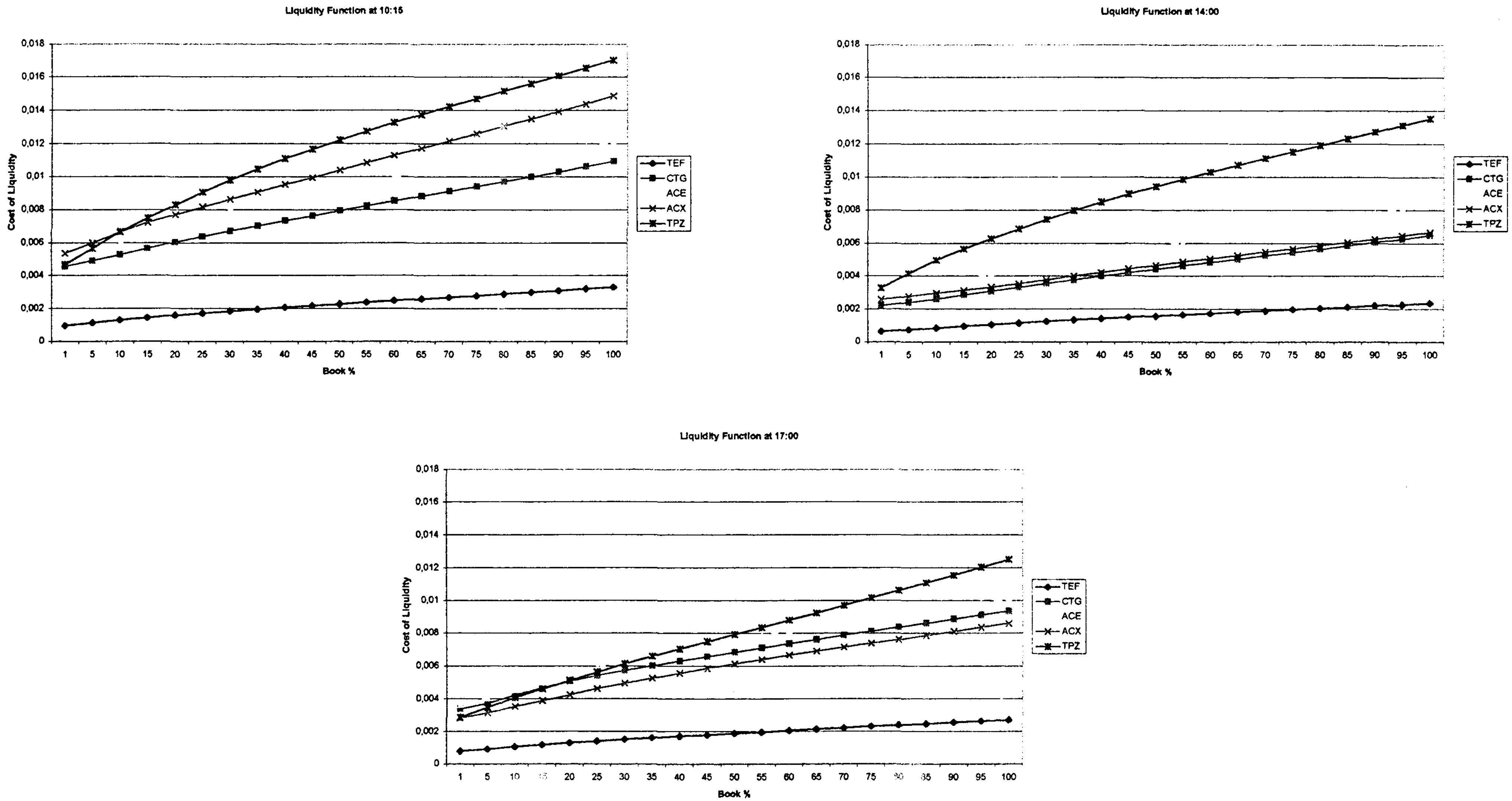
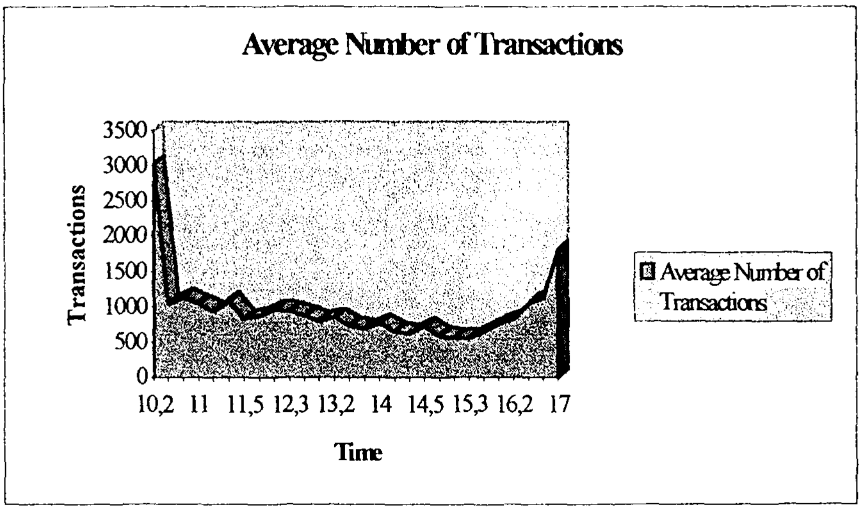

Liquidity Function at 10:15
Cost of Liquidity
Book %
TEF
CTG
ACE
ACX
TPZ
Liquidity Function at 14:00
Cost of Liquidity
Book %
TEF
CTG
ACE
ACX
TPZ
Liquidity Function at 17:00
Cost of Liquidity
Book %
TEF
CTG
ACE
ACX
TPZ

FIGURE 4


Average Number of Transactions
Transactions
3500
3000
2500
2000
1500
1000
500
0
10,2
11
11,5
12,3
13,2
14
14,5
15,3
16,2
17
Time
Average Number of Transactions